Anatomy of the Kidneys: The Paired Heterocrine Organs

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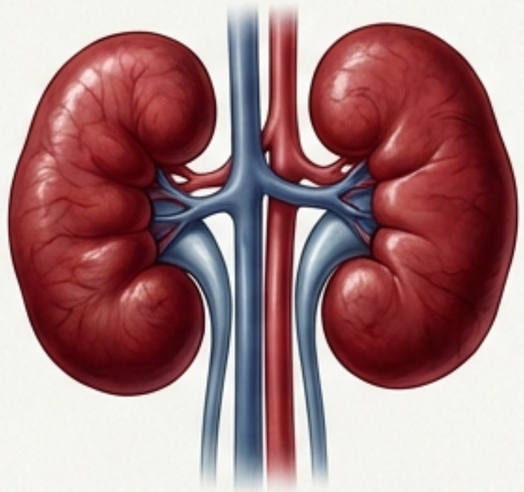

Core Definition

The kidneys are defined as paired, symmetrical, retroperitoneal organs located on either side of the dorsolumbar spine.

Primary Roles

- Heterocrine Function: Possessing both endocrine (hormonal) and exocrine (waste excretion) capabilities.
- Homeostasis: Essential for systemic regulation of fluids, electrolytes, and blood pressure.

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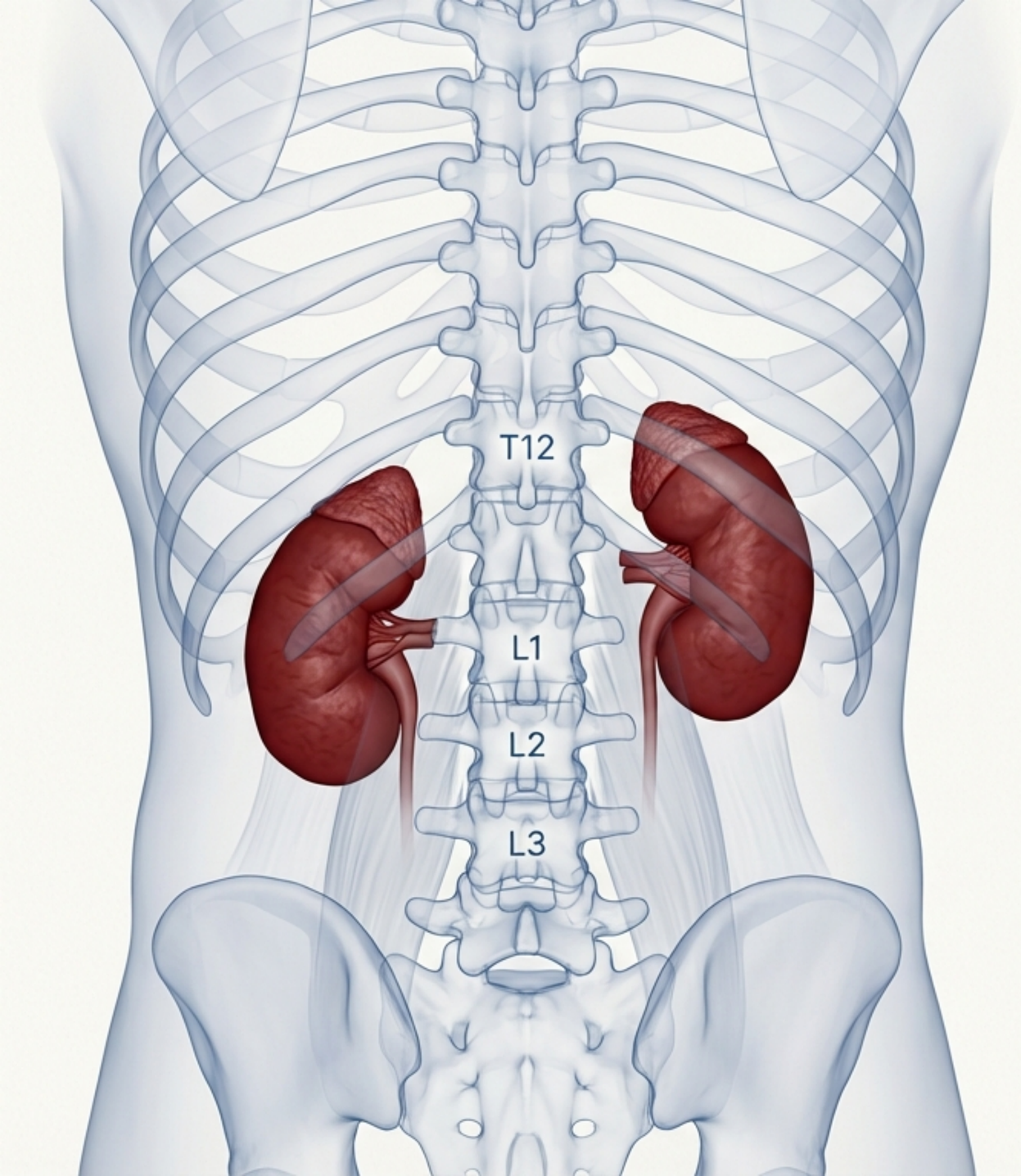

Vertebral Location and Surface Anatomy

Vertebral Levels

The kidneys span from approximately T12 to L3.

Asymmetry

- Right Kidney: Positioned slightly lower due to the bulk of the right lobe of the liver.
- Left Kidney: Positioned slightly higher; the upper pole may overlie the 11th rib.

Rib Relations

The upper poles are protected by ribs 11 and 12. The lower poles are usually below the rib cage.

Orientation

They lie high on the posterior abdominal wall, obliquely parallel to the lateral border of the psoas major muscle.

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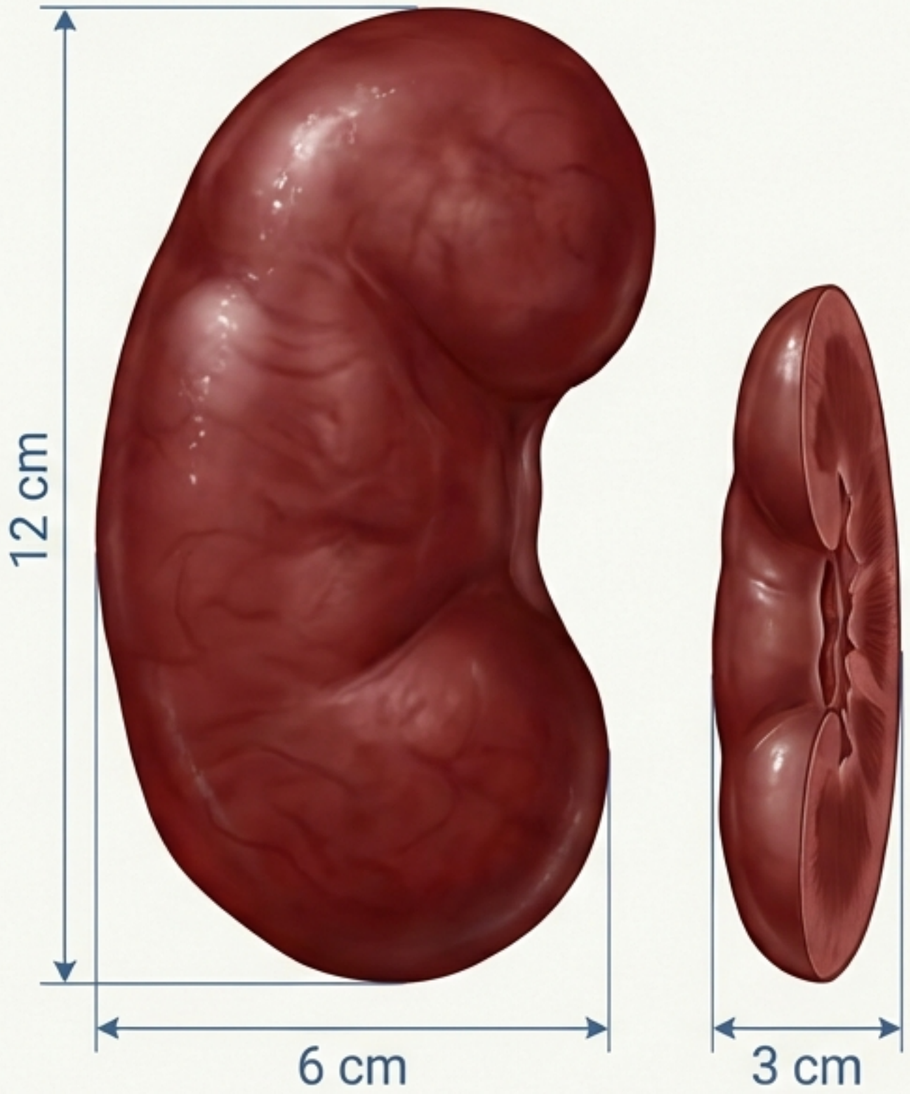
External Morphology and Dimensions

Shape & Appearance:

Bean-shaped organs flattened anteroposteriorly. Dark red color with a smooth consistency and traces of lobulation, covered by a glistening fibrous capsule.

Mobility: Moves vertically ~2 cm during respiratory excursion.



Spec Sheet

Standard Dimensions (Normal Kidney)

- **Length**: 12 cm
- **Width**: 6 cm
- **Thickness**: 3 cm
- **Weight**: 130 g

External Borders

- **Lateral**: Convex
- **Medial**: Vertical with a slit-like depression (the hilum) transmitting renal vessels and nerves.

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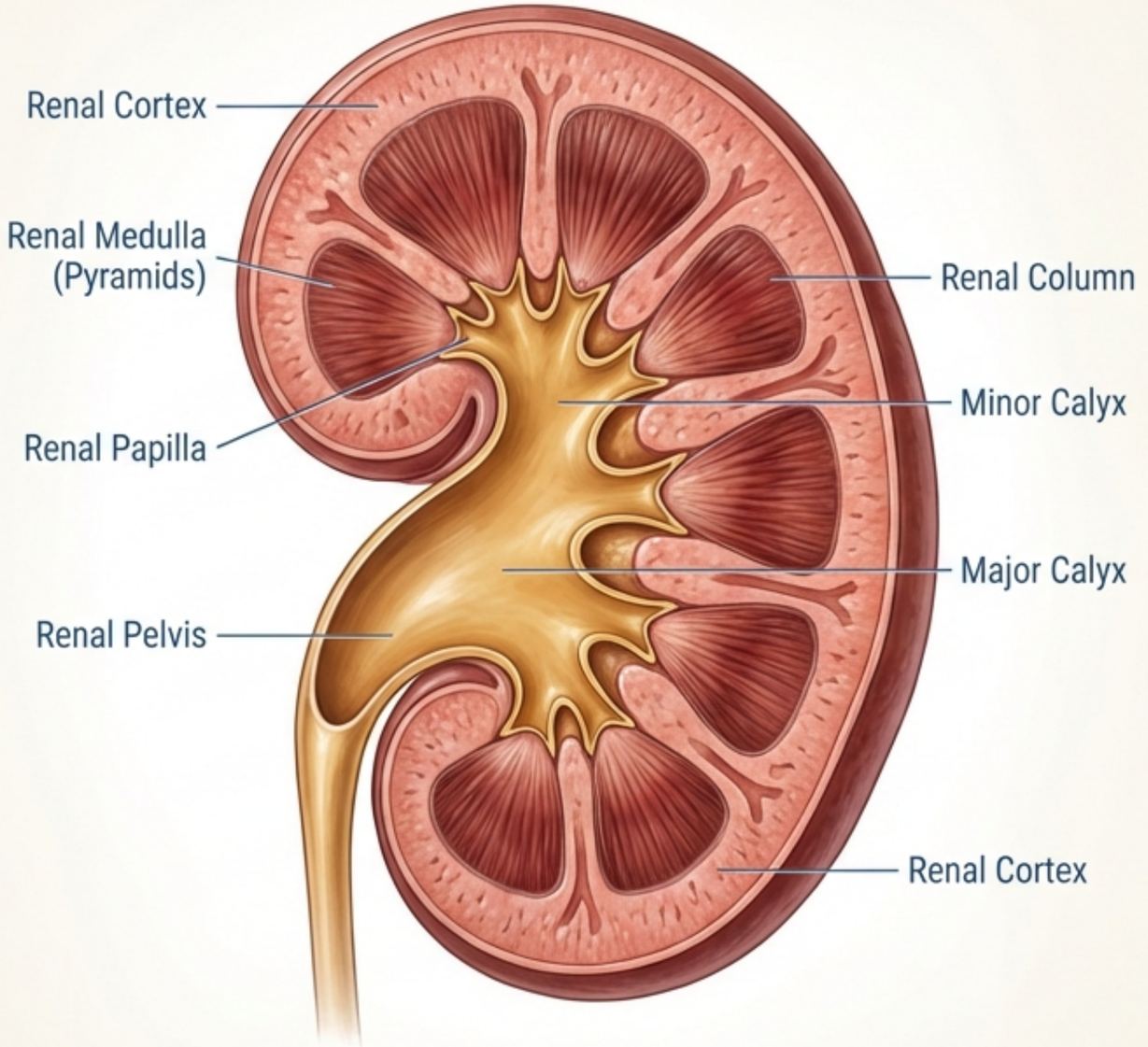
Internal Architecture: Cortex, Medulla, and Collecting System

Parenchyma Structure

- **Cortex:** Dark reddish outer layer beneath the capsule. Extends inward as ‘Renal Columns'.
- **Medulla:** Composed of darker, triangular striated areas known as Pyramids. Apex forms a ‘Renal Papilla’.

The Collecting System (Urine Flow)

- **Minor Calyces:** 7–13 small funnels that cup the renal papillae.
- **Major Calyces:** 3 medium funnels formed by the convergence of minor calyces.
- **Renal Pelvis:** A funnel-shaped muscular reservoir (capacity <5 ml), narrowing to become the ureter.



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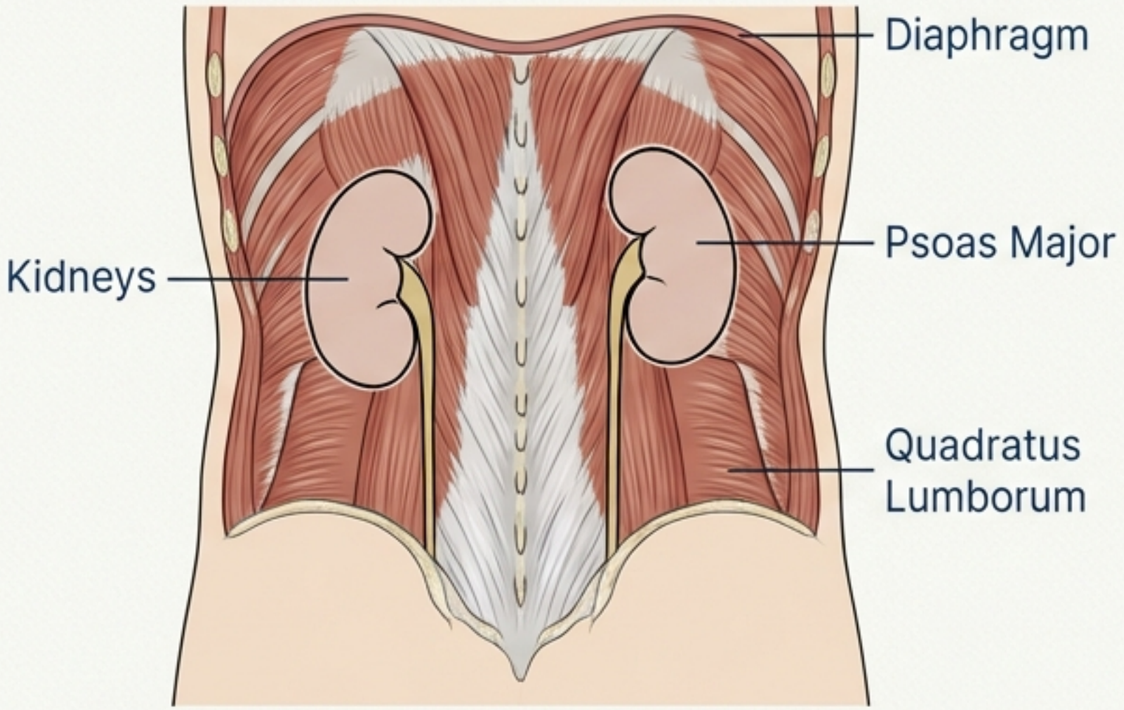
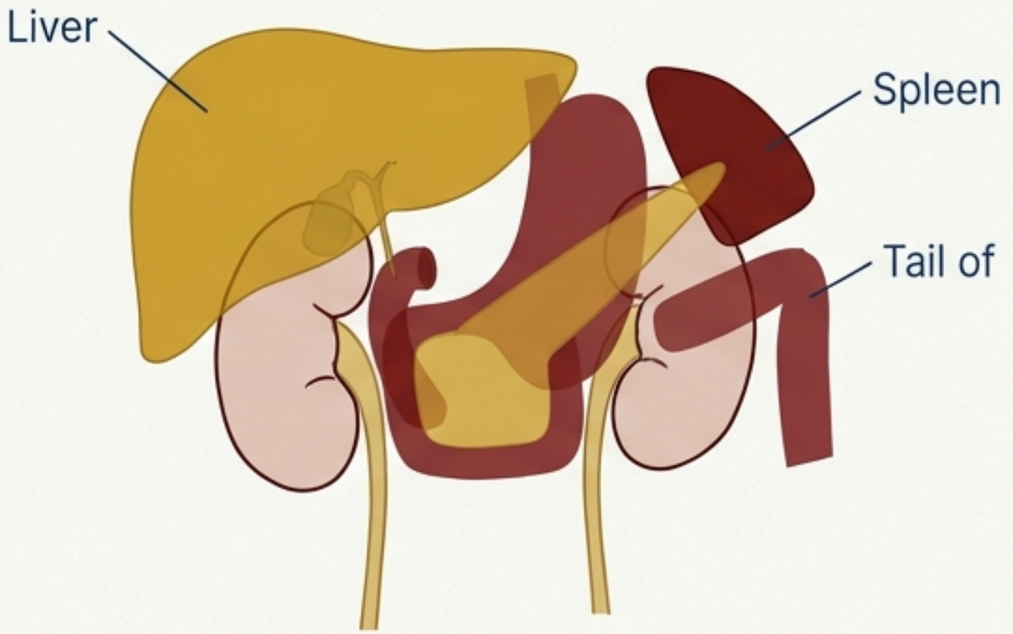
Anatomical Relations: Posterior and Anterior

Posterior Relations (Both Kidneys)



- **Thoracic Level:** Diaphragm, costodiaphragmatic recess, 11th/12th ribs.
- **Lumbar Level:** Psoas major, Quadratus lumborum, Transversus abdominis.

Anterior Relations (Asymmetrical)



- **Right Kidney:** Liver (hepatorenal pouch), 2nd part of duodenum, hepatic flexure, jejunal coils.
- **Left Kidney:** Stomach, spleen, tail of pancreas, splenic flexure, jejunal coils.

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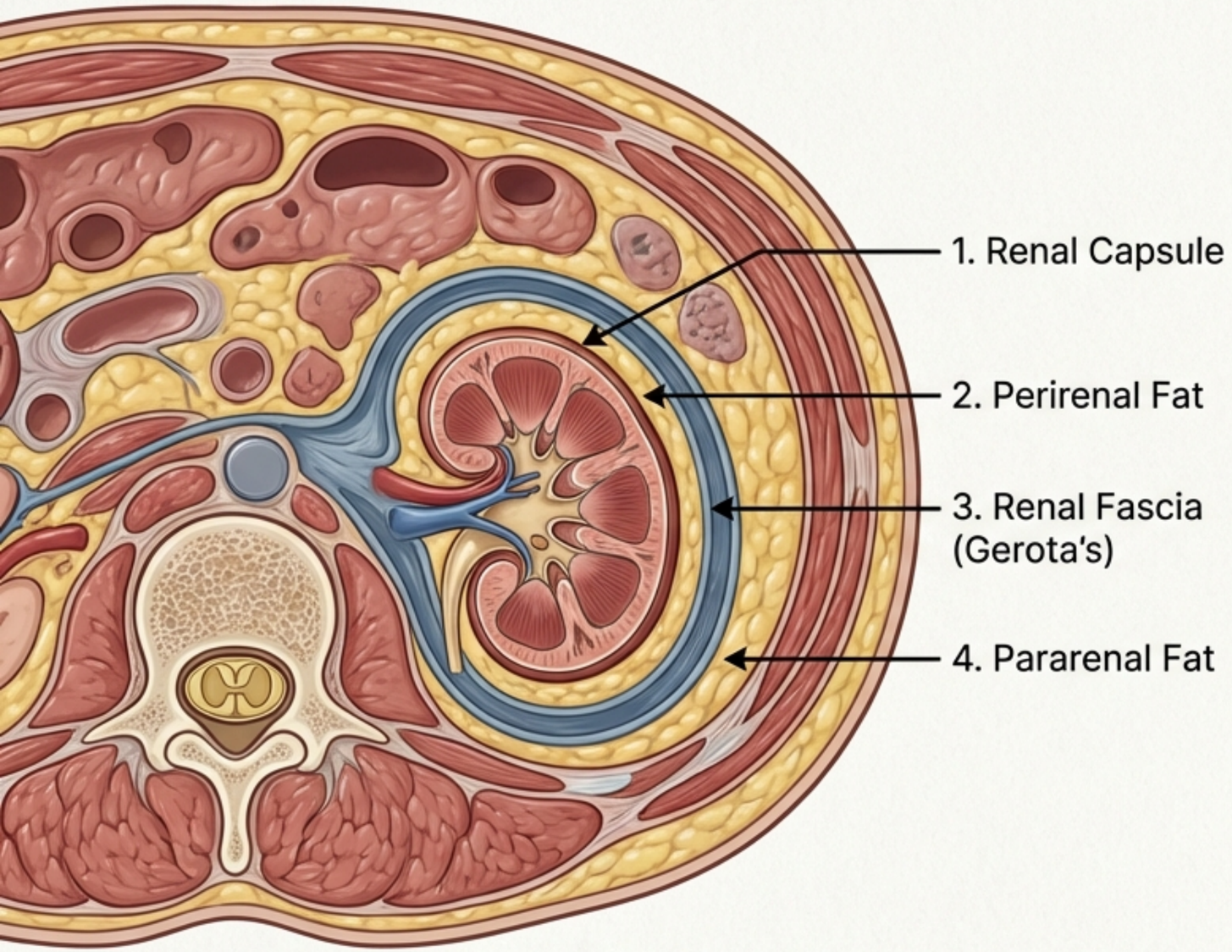

Means of Fixation and Protection

The "Onion" Layers (Inside Out)

1. **Renal (Fibrous) Capsule:** Tough connective tissue maintaining shape.
2. **Perirenal Fat:** Cushioning layer directly surrounding the kidney.
3. **Renal Fascia (Gerota's Fascia):** Anchors the kidney to the posterior abdominal wall.
4. **Pararenal Fat:** Retroperitoneal fat outside the fascia.

Additional Support

- **Vascular Pedicle:** Renal artery and vein act as tethers.
- **Abdominal Tone:** Intra-abdominal pressure from wall muscles.

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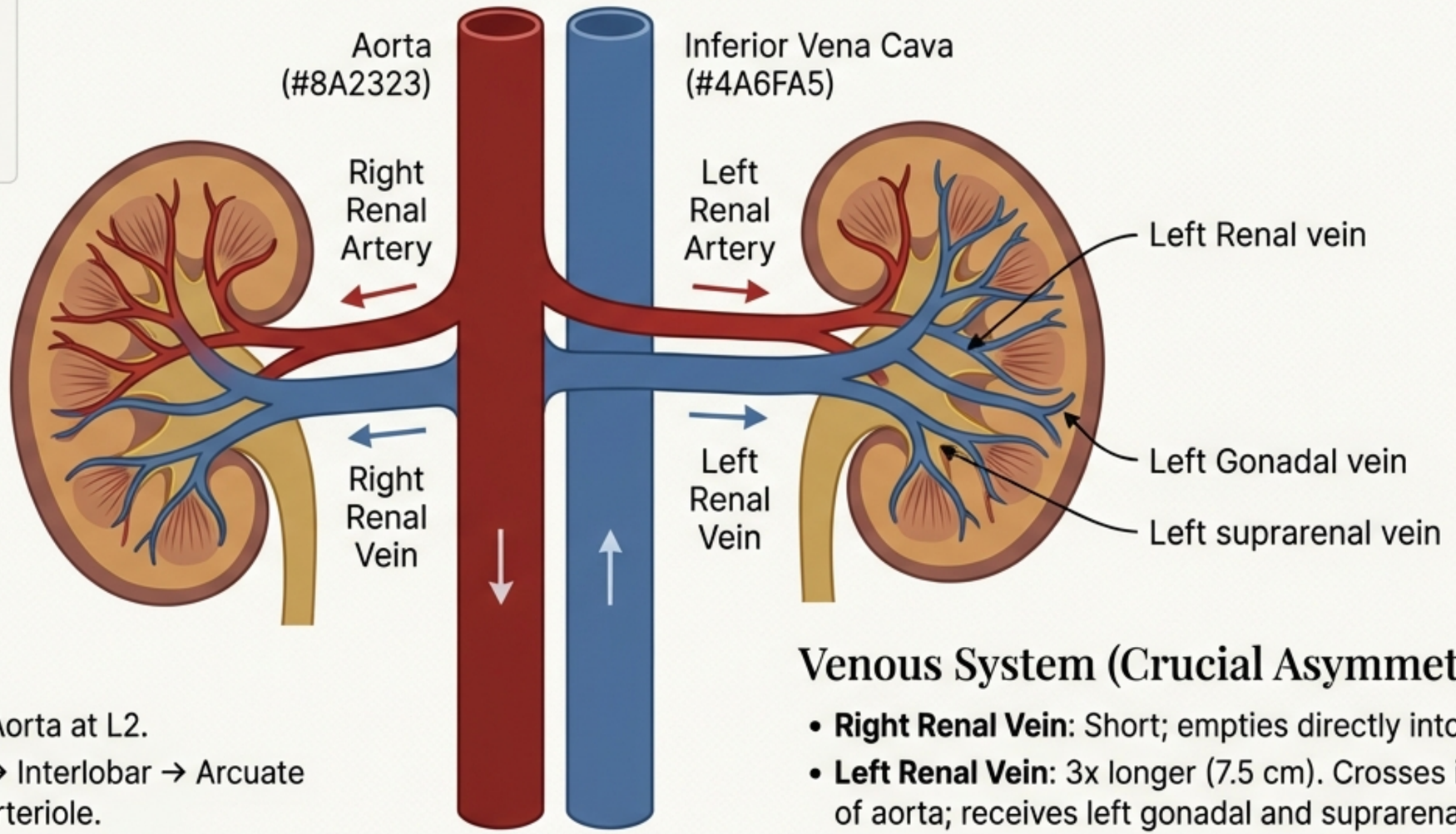
Vascular Supply: Arteries and Veins

Blood Volume

Kidneys receive 20–25% of cardiac output (approx. 1.2–1.3 L/min).

Tree



Arterial System

- **Renal Arteries**: Arise from Aorta at L2.
- **Branching**: Segmental (5) → Interlobar → Arcuate → Interlobular → Afferent Arteriole.

Venous System (Crucial Asymmetry)

- **Right Renal Vein**: Short; empties directly into IVC.
- **Left Renal Vein**: 3x longer (7.5 cm). Crosses in front of aorta; receives left gonadal and suprarenal veins.

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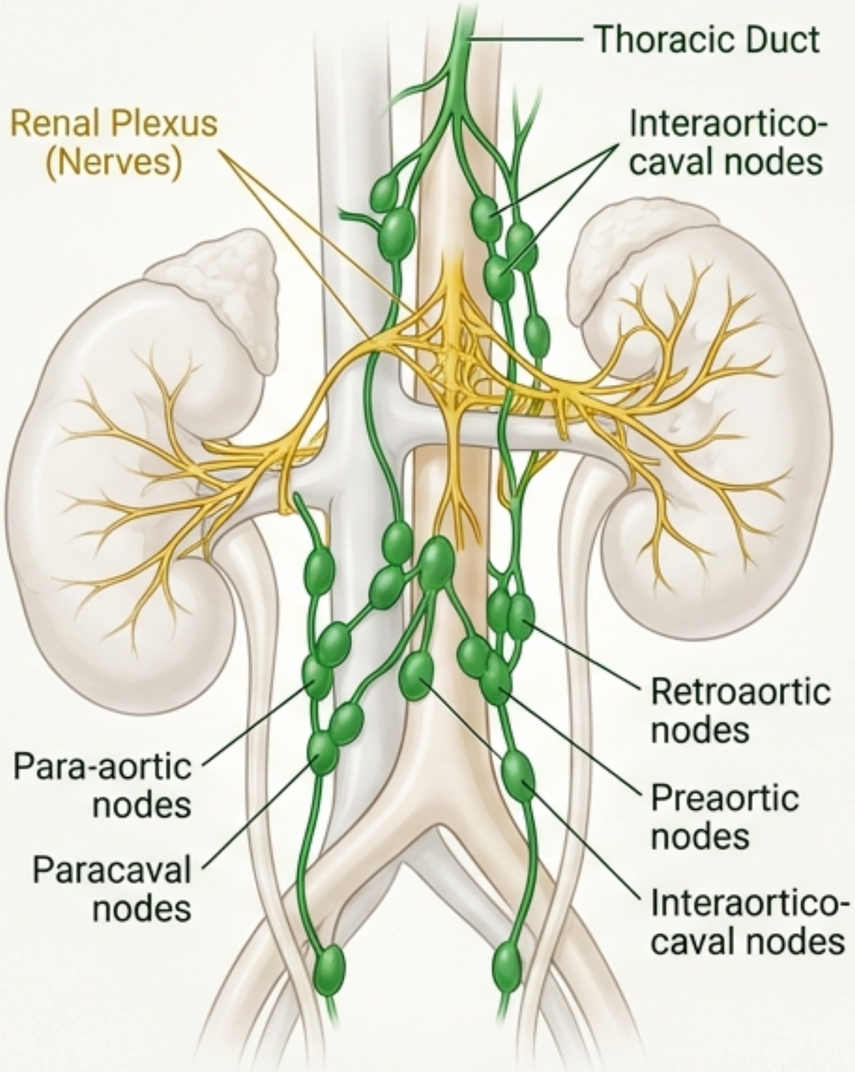
Innervation and Lymphatic Drainage

Nerve Supply

- **Sympathetic (T10–L2)**: Controls vasoconstriction and renin release. Pain signals travel via splanchnic nerves (flank pain radiating to groin).
- **Parasympathetic**: Vagus nerve (CN X).



Lymphatic Drainage

- **Origin**: Renal parenchyma, capsule, and calyces.
- **Left Nodes**: Para-aortic nodes.
- **Right Nodes**: Paracaval and Interaortico-caval nodes.
- Clinical Relevance: Major route for tumor spread.

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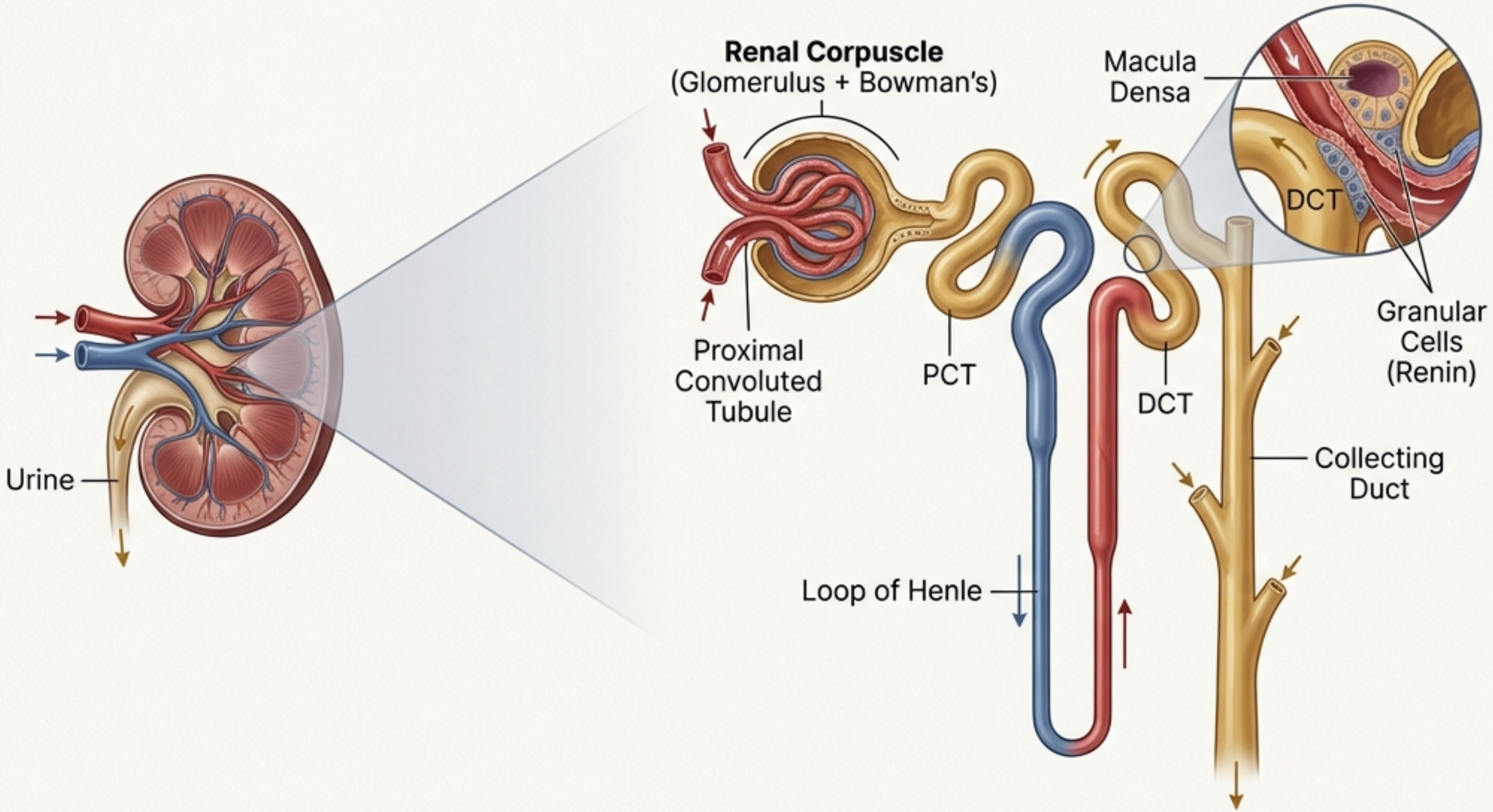
The Nephron: The Microscopic Functional Unit

Approximately 1 million nephrons per kidney.



Components:

1. **Renal Corpuscle:** The filter. (Glomerulus, Bowman's capsule)
2. **Tubule System:** Processors of filtrate. (PCT, Loop of Henle, DCT, Collecting Duct)
3. **Juxtaglomerular Apparatus (JGA):** Control center. Contains Granular Cells (Renin secretion) and Macula Densa (NaCl sensor).

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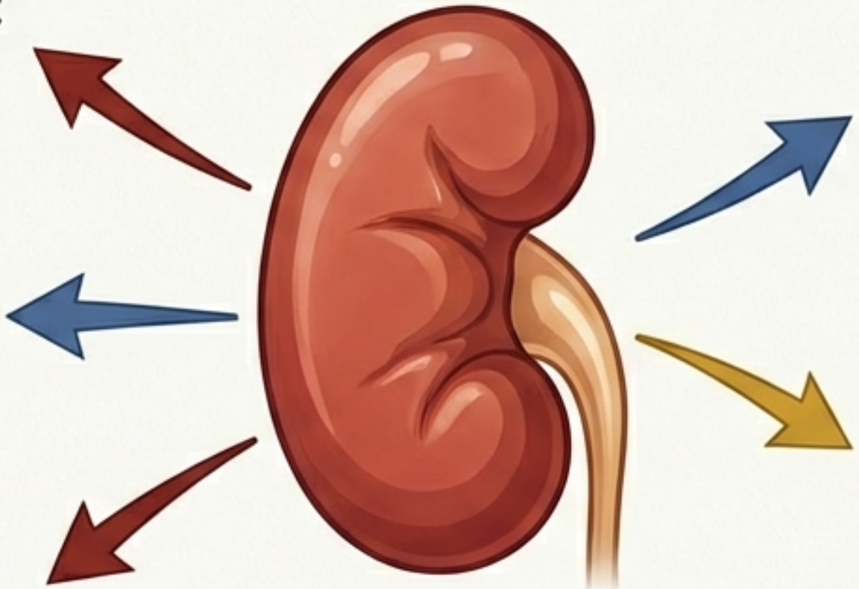
Dual Functionality: Endocrine and Excretory Roles

Endocrine Functions (Hormone Secretion)

- **Erythropoietin (EPO):** Stimulates RBC production.

- **Renin:** Regulates blood pressure (RAAS).

- **Calcitriol:** Active Vitamin D for Ca/Phosphate metabolism.



Exocrine/Excretory Functions

- **Waste Elimination:** Urea, Creatinine, Uric acid, toxins.

- **Homeostasis:** Water balance, Electrolytes (Na+, K+), Acid-base balance (pH 7.35-7.45), Blood Pressure.

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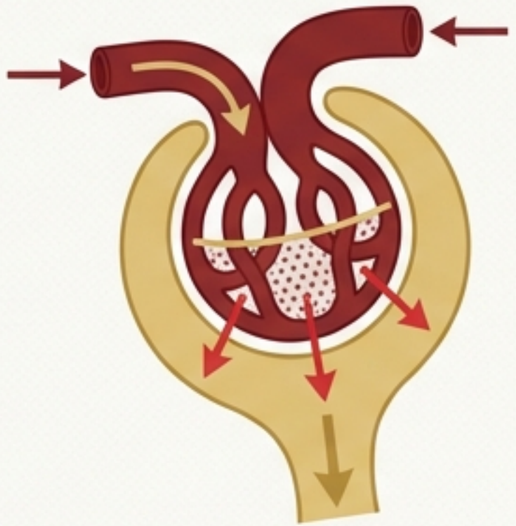
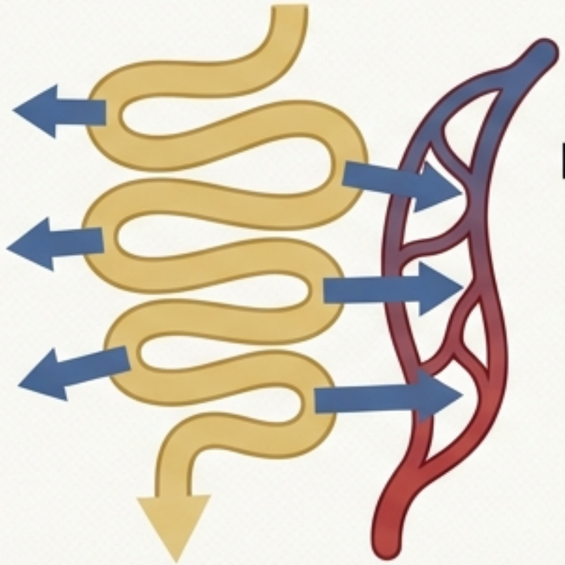
Urine Formation I: Filtration and Mass Reabsorption

Step 1: Filtration



Plasma filtered → Primary urine.
Contains freely filtered substances (Urea, Creatinine, Glucose, Ions).

Step 2: Mass Reabsorption



PCT: The “Bulk” worker.

- Reabsorbs ~65–70% water and sodium.
- 100% Reabsorption: Glucose and Amino acids.
- Secretes: H^+, NH_4^+, drug metabolites.

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Urine Formation II: Concentration and Fine Regulation

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Step 3: Concentration (Loop of Henle)

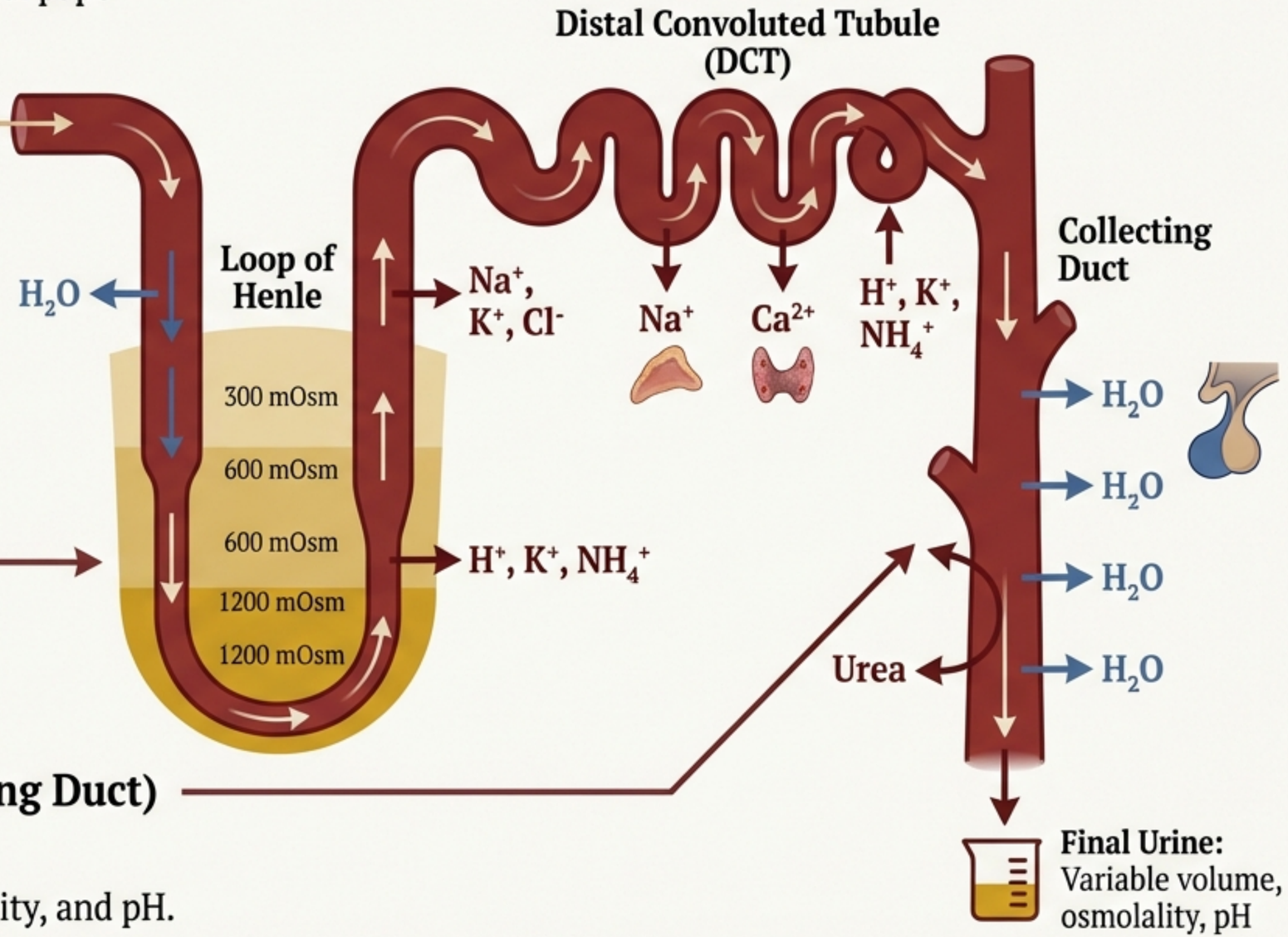
- Descending Limb: Permeable to water (reabsorption).
- Ascending Limb: Impermeable to water; active $Na^+/K^+/Cl^-$ transport. Establishes osmotic gradient.

Step 4: Fine Regulation (Distal Convoluted Tubule)

- Reabsorption of Sodium (Aldosterone) and Calcium (PTH).

Step 5: Final Adjustment (Collecting Duct)

- Water reabsorption regulated by ADH.
- Determines final urine volume, osmolality, and pH.



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Clinical Pathology: Failure and Infection

Acute Kidney Injury (AKI)	Chronic Kidney Disease (CKD)	Infections (UTI)
Sudden decrease in function. • **Pre-renal:** Hypotension/Hypovolemia • **Renal:** Tissue damage (toxins) • **Post-renal:** Obstruction	**Progressive, irreversible loss.** • **Definition:** GFR <60 ml/min for ≥3 months. • **Major Causes:** Diabetes, Hypertension.	**Bacterial infection (Pyelonephritis).** • **Pathogen:** Commonly E. coli. • **Symptoms:** Fever, flank pain, dysuria.

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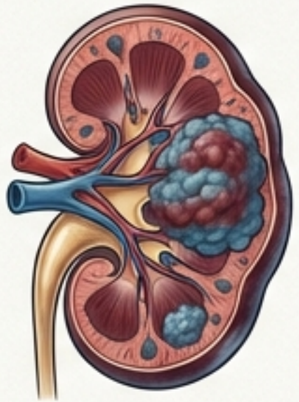
Clinical Pathology: Obstruction and Malignancy

Kidney Stones (Nephrolithiasis)

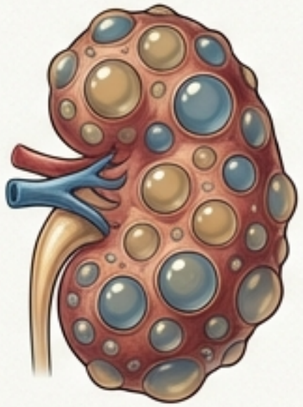
- Solid crystalline deposits (Calcium oxalate most common).
- Symptoms: Severe flank pain, hematuria, hydronephrosis.

Malignancy (Kidney Cancer)



- Uncontrolled cell proliferation.
- Symptoms: Enlarged kidneys, hematuria, weight loss.

Structural/Genetic



- Polycystic Kidney Disease (PKD): Multiple cysts leading to failure.
- Glomerular Disorders: Nephrotic Syndrome (Proteinuria >3g) vs Nephritic Syndrome (Hematuria/HTN).

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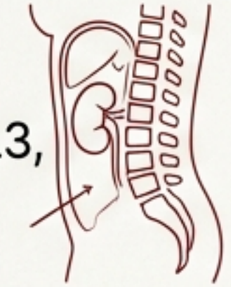
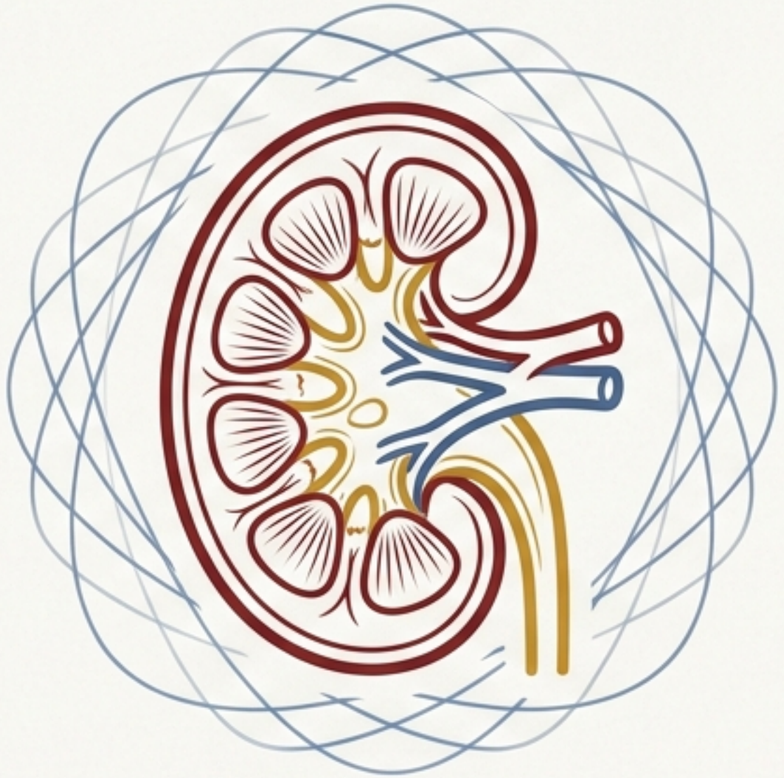
Key Takeaways: The Master Regulator

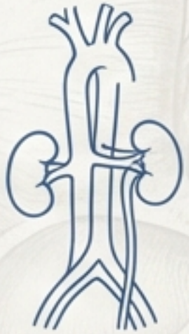
Anatomy



Retroperitoneal, T12-L3, encased in protective fascia (“The Onion”).



Vascular

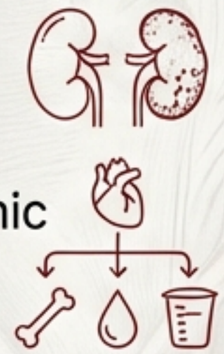


Receives 25% cardiac output. Left Renal Vein is significantly longer than the Right.

Functional

Body’s Chemist: pH, electrolytes, BP control. Endocrine Gland: Renin, EPO, Vitamin D.

Clinical



Vital organ. Damage (AKI/CKD) has systemic consequences from anemia to uremia.

Multifunctional organs essential for systemic homeostasis.

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